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WEAPON SYSTEMS 133B. FLIGHT-TEST FIRING OF SECOND STAGE WING VI--ETC(U)
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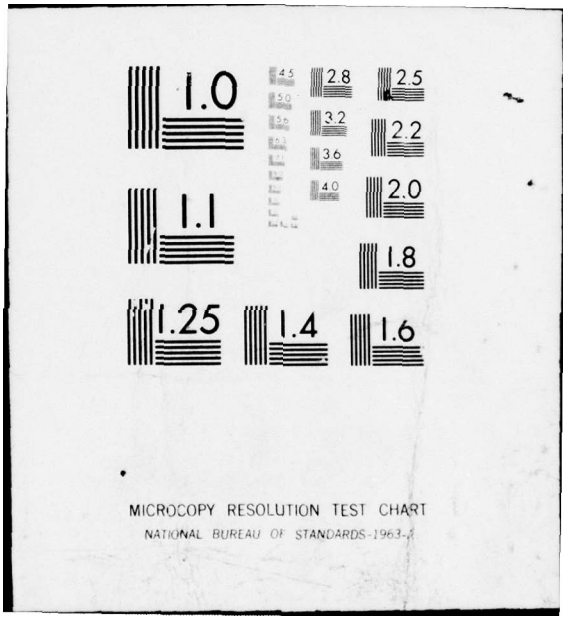
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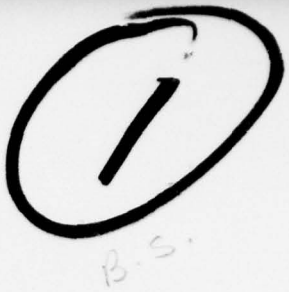

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WEAPON SYSTEMS 133B

FINAL REPORT

FLIGHT-TEST FIRING OF SECOND STAGE WING VI MINUTEMAN MOTOR STM-13W (52PQA6-81)

Report 0162-02TR-STM-13W 10 May 1977

aerojet solid propulsion company
P. O. BOX 13400 SACRAMENTO, CALIFORNIA 95813 • A DIVISION OF AEROJET-GENERAL

14 ASPC-

Report 0162-02TR-STM-13W

6 WEAPON SYSTEMS 133B

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9 Final rept.

15 Contract F04704-75-C-0038

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A DIVISION OF AEROJET GENERAL

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FIGURE LIST

I. SUMMARY

Minuteman III Special Test Missile 13W (STM-13W), with Aerojet-supplied Second Stage Motor AA21485 (PQA6-81), was successfully fired from the Western Test Range (WTR) on 30 January 1977. The missile was tested from Launch Facility 21; range zero time was approximately 2205 hr P.s.t. (0505:00.417 hr 31 January 1977 UTC). Performance of the second stage motor was satisfactory and all measured performance parameters were within model specification limits.

The motor ignited satisfactorily and operated for an action time of 65.56 sec. Second stage skirt jettison occurred 16.49 sec after Stage II ignition.

Performance of the liquid injection thrust vector control and roll control system was within model specification limits. Injectant utilization was 119.6 lb.

II. TEST OBJECTIVES AND MOTOR DESCRIPTION

A. TEST OBJECTIVE

The primary objective of the flight test is classified; a secondary objective was to demonstrate the reliability and reproducibility of the operational second stage motor and the capability of the PQA motor to operate within model specification limits.* Successful accomplishment of these objectives was a requirement for the qualification of a 19-motor second-stage production lot.

* Model Specification S-133-1002-0-2A, Model Specification, Motor, Rocket SR-19-AJ-1, Solid Propellant, Operational, dated 14 March 1973.

II. Test Objectives and Motor Description (cont)

B. MOTOR DESCRIPTION

Motor SN AA21485 was a standard Minuteman III production quality assurance motor modified to the operational configuration. The motor was fabricated in accordance with Drawing 382100-189AF. The motor incorporated no new material, processes, or vendor changes that had not been previously flight tested.

The modification of the motor from the PQA static test configuration to the operational configuration consisted of replacing the static test igniter adapter and deleting the static LITVC injector valves. The change of igniter adapters precludes measurement of igniter chamber internal pressure which is not a flight test data parameter. Operational P90 ACI units provided by the guidance and control associate contractor are utilized instead of the Aerojet-supplied Moog injector units used in static tests. The two types of injector valves provide identical functional performance but are different in compatibility with the flight and static test control systems.

Propellant physical properties were as follows:

	67 VM		
	4954	4955	4956
Liquid-strand burning rate, in./sec*	0.3350	0.3370	0.3365
3KS-500 burning rate, in./sec	0.3254	0.3300	0.3353
Liquid density, gm/cc	1.7700	1.7700	1.7715
Initial tangent modulus, psi**	477	486	444
Maximum stress, psi* (77°F)	95.1	97.2	96.5
Elongation at maximum stress, % (77°F)	33.1	32.7	34.4
Shore hardness at end of cure	50	50	50

* 80°F at 700 psia
** 12-day cure at 110 ± 5°F

II. Test Objectives and Motor Description (cont)

C. NONDESTRICTIVE TESTING

Motor SN AA21485 was radiographically examined in the Aerojet nondestructive test facility with a 10 MEV linear accelerator as the radiation source. The examination revealed no defects.

D. INSTRUMENTATION

The motor was instrumented with the standard flight test instrumentation, operational pressure transducers, and LITVC injector valve position transducers. The instrumentation was sufficient to evaluate motor performance although all operating characteristics normally associated with static testing cannot be evaluated. The items that cannot be evaluated are:

1. Igniter internal pressure: Instrument not installed.

2. Interstage pressure at ignition: Measurement and prediction based on chamber pressure are not possible because of slow sampling rate.

3. LITVC side force and injectant expulsion capability: Not evaluated because flight test requirements are different and significantly less than the specified PQA test duty cycle.

4. Roll Control Valve response time: Instrumentation not installed.

Test instrumentation was as follows:

II.D. Instrumentation (cont)

Parameter	Measurement Designation
Motor Chamber Pressure	OAF03
LITVC Manifold and Pressure	OAT02
Roll Control Gas Generator Pressure	OAG01
LITVC Pintle Position	DAU01 through 4
Roll Control Valve Actuation Commands	GGU06 and GGU07

III. TEST RESULTS

A. SUMMARY

Minuteman Special Test Missile 13W, with Aerojet Second Stage Motor AA 21485 (PQA6-81), was successfully fired from Western Test Range Launch Facility on 30 January 1977. Range zero time was approximately 2205 hr P.s.t. (0505:00.417 31 January 1977) UTC. The second stage motor operated normally for a duration of 64.45 sec. Ballistic and control system performance were satisfactory. Flight event times were as follows:

Event	Time, sec
Stage I Ignition	0.0
Stage II LITVC/RC Discrete	60.246
I-II Discrete	61.746
Stage II Skirt Jettison	78.24
Stage III LITVC/RC Discrete	125.199
Shroud Eject Discrete	125.397
Stage II Motor Pc = 28 psia	126.189
II-III Discrete	126.559

III. Test Results (cont)

B. IGNITION AND STAGING

The motor ignited satisfactorily at an altitude of approximately 98,000 ft. Chamber pressure during ignition is compared with model specification limits in Figure 1. The estimated ignition delay of 105 millisec and maximum ignition pressure of 452 psia are very close to the average values of 108 millisec and 454 psia, respectively, for static firing. These values are estimated because of the normal occurrence of telemetered data dropout during motor ignition. Although internal igniter pressures were not measured, the normal ignition implies satisfactory igniter performance.

C. BALLISTIC PERFORMANCE

Motor chamber pressure during action time was within model specification limits (Figure 2). Motor action time was 64.45 sec and the maximum chamber pressure was 540 psia at the estimated temperature of 70°F. The log book predicted values for these parameters, corrected to 70°F, are 64.48 sec and 538 psia, respectively. The action time of 64.45 sec at 70°F was within specification limits.

Vacuum thrust during action time, derived from flight guidance acceleration data, was well within model specification limits (Figure 3). On the basis of these data, the motor produced a delivered action time total impulse of 3,954,873 lb-sec. A 2400 lb-sec correction from the near-vacuum flight condition to vacuum condition resulted in an action time vacuum impulse of 3,959,373 lb-sec; the indicated vacuum specific impulse of 288.18 lbf-sec/lbm was 0.78 lbf-sec/lbm higher than the static test average. Vacuum thrust was within required limits (Figure 4); tailoff time from 41,000 lbf to 2000 lbf was 1.53 sec (corrected to 80°F). A plot of motor action time for a propellant temperature of 70°F is also shown in Figure 4.

III.C. Ballistic Performance (cont)

Derived ballistic data are tabulated in Figure 5, and motor performance values are compared with model specification requirements in Figure 6. Acceptance control data for average thrust, total impulse, thrust decay time, and motor action time are shown in Figures 7 and 8.

D. THRUST VECTOR CONTROL

1. LITVC Subsystem

LITVC subsystem performance was satisfactory throughout motor action time. System pressurization was achieved 0.143 sec from the LITVC gas generator ignition discrete, the specified maximum delay time is 0.880 sec. System pressure was also maintained within specification limits after the pressurization transient (Figure 9). LITVC pressure regulation during the interval between system initiation and the I-II staging discrete (Figure 9) was normal and consistent with that of static test PQA motors.

Total injectant utilization during Stage II operation was 119.6 lb or 57% of the minimum expendable injectant weight. This utilization is not comparable with PQA test requirements since it represents the amount of injectant actually required for flight attitude control rather than the PQA duty cycle which is programmed to demonstrate total injectant expulsion capability. The amount used for normal attitude control was 57.6 lb or 27% of the expendable weight and is typical of past flight test experience. Injectant expended through the yaw injectors during the injectant dump cycle between 5.1 and 12.3 sec was 62 lb. A summary of injectant utilization is as follows:

III.D. Thrust Vector Control (cont)

Injector	Flow for Attitude Control, lb
1	1.9
2	7.0
3	28.3
4	20.4
Total	57.6

Total Control, lb	57.6
Dump through yaw injectors, lb	62.0
Total injectant expended	119.6

LITVC system side force capabilities were not evaluated with PQA model specification requirements because the maximum side force and jet deflection required during the flight test were only approximately 525 lbf during the first 3 sec and 0.46 degrees thereafter. The values are considerably less than the 3800 lb side force and 2 degree jet deflection minimum capabilities demonstrated during the static PQA tests. LITVC performance is compared with specification limits in Figure 10.

2. Roll Control Subsystem

Roll control (RC) subsystem performance was satisfactory and within specification limits. Roll control moment capability was attained 162 millisec after the generator ignition discrete when the RC gas generator pressure increased to the required 1560 psia. The maximum pressure of 2185 psi occurred at 224 millisec and was below the specified MEOP of 2400 psi. Gas generator pressure-vs-time curves are shown in Figure 11. Gas generator chamber pressure was within specification limits throughout the test. The minimum torque capabilities were as follows: 4.3 ft-lb from 0.7 to 7.7 sec after the gas generator discrete time, 144 ft-lb to 15.7 sec, and 89 ft-lb at the end of Stage II action time.

III.D. Thrust Vector Control (cont)

The roll control gas generator exhibited the abnormally fast ignition transient typical of the lot 505R generators. Similar fast ignitions occurred during the static test of Motor 52PQA6-80 and during the STM-11W and -12W flight tests. However, the STM-13W ignition does not violate any specification requirement and the maximum pressure was well below the specification maximum. The roll control gas generator ignition transient is compared with that of Motor 52PQA6-80 and with a normal test (PVM-13) in Figure 12.

Roll control valve response times could not be evaluated with respect to model specification requirements because of the lack of instrumentation. However, performance of the valve is considered satisfactory based on adequate control of the missile in the roll attitude during motor operation. Only minimal roll control utilization, 4 clockwise and 20 counterclockwise commands, were required.

Roll control performance is summarized and compared with PQA model specification requirements in Figure 10.

E. INSTRUMENTATION PERFORMANCE

Instrumentation and telemetry system performance was satisfactory and provided adequate data for the evaluation of motor performance.

F. MOTOR RELIABILITY

Post-test reliability data are presented in Figure 13.

IV. CONCLUSIONS AND RECOMMENDATIONS

Overall performance of the second stage motor was satisfactory. The motor operated for an action time of 64.45 sec; all available performance

IV. Conclusions and Recommendations (cont)

parameters were within specification limits. Performance of the LITVC and RC subsystems was satisfactory.

The flight test of Motor STM-13W (52PQA6-81) was the qualification test for Production Motors Air Force SN 21469 through 21475 and 21477 through 21489. Aerojet recommends that Motor 52PQA6-81 used in STM-13W be accepted as a successful Wing VI Quality Assurance Motor.

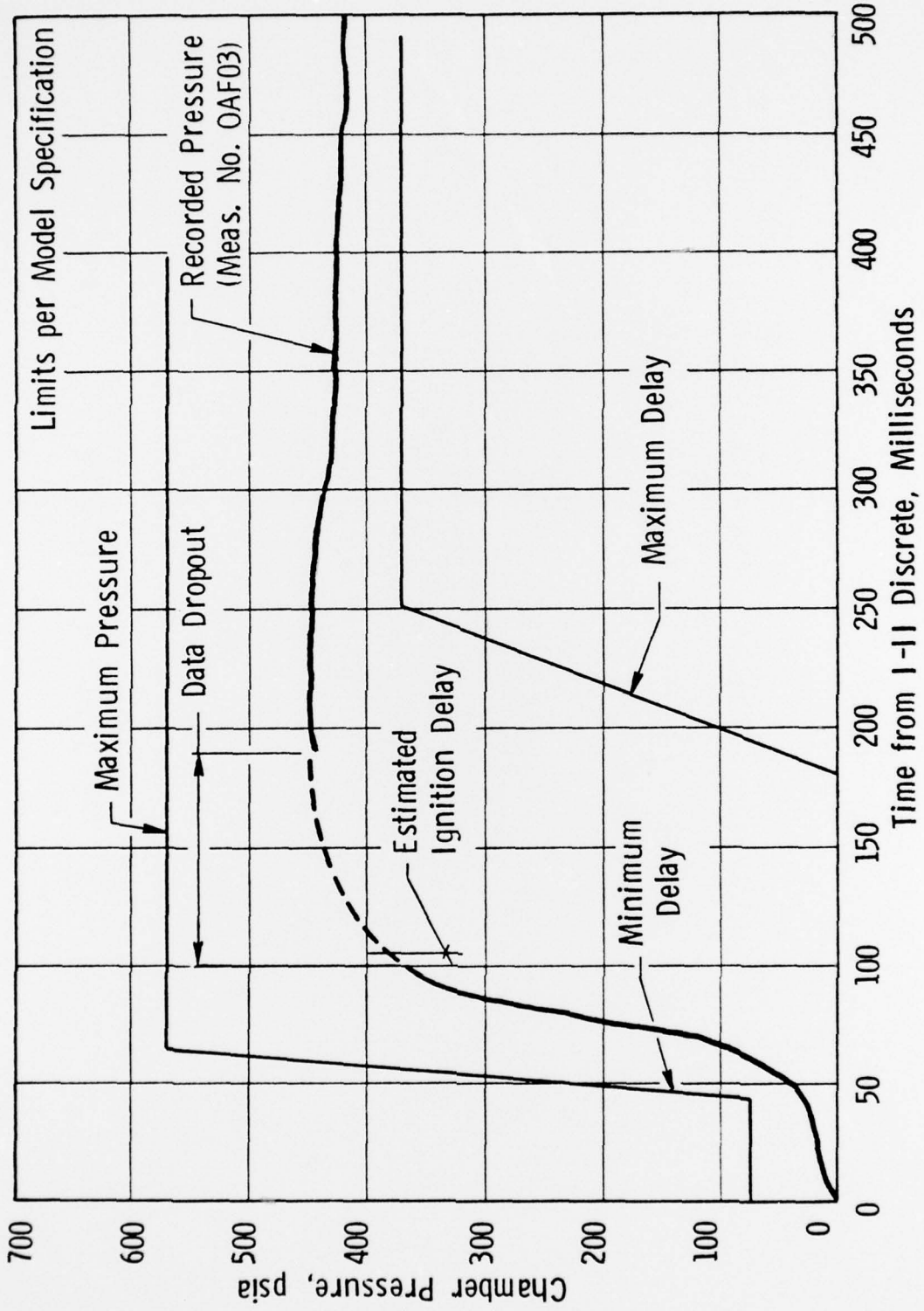


Figure 1

Chamber Pressure During Ignition, 60 to 80°F

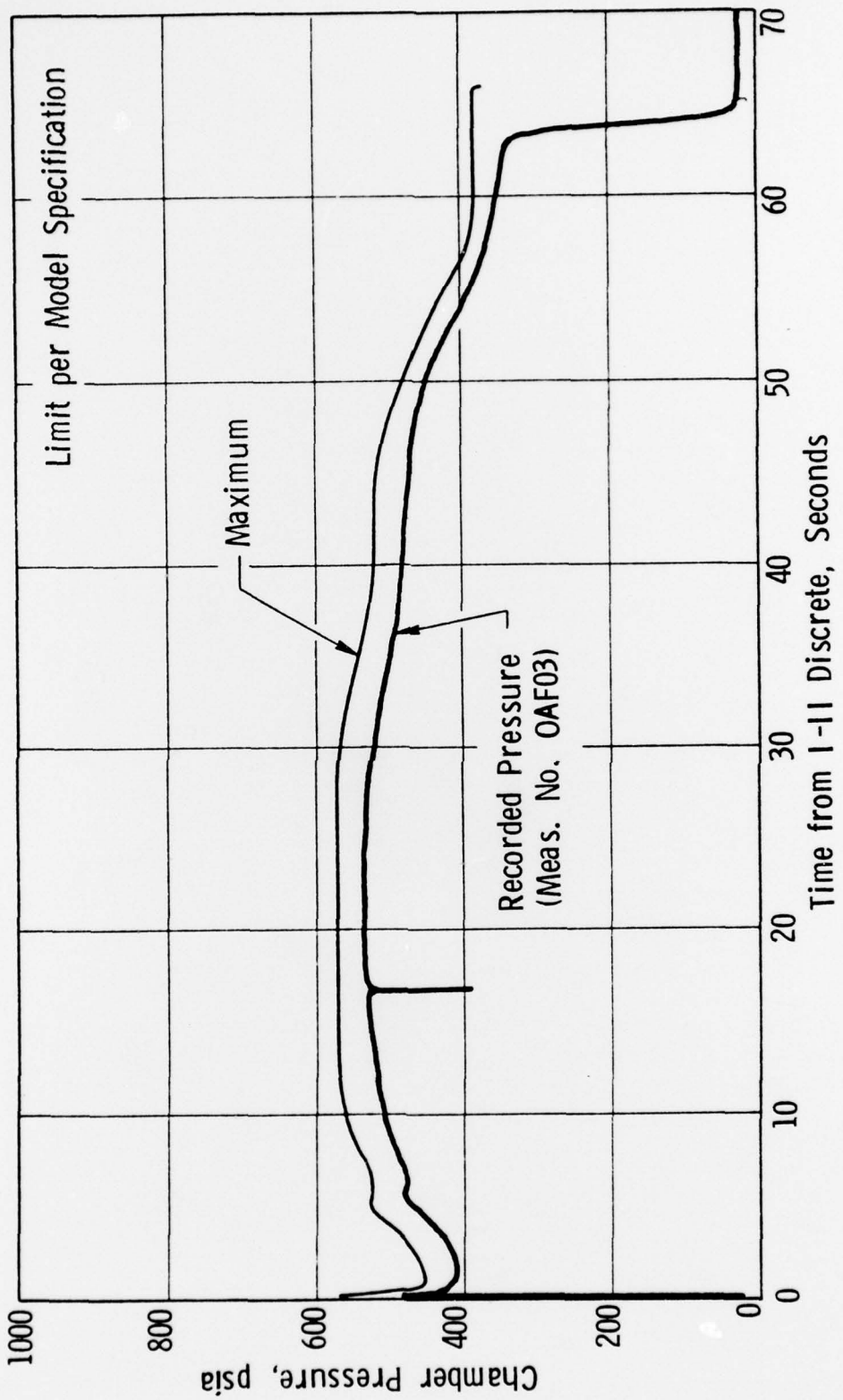


Figure 2

Chamber Pressure vs Time

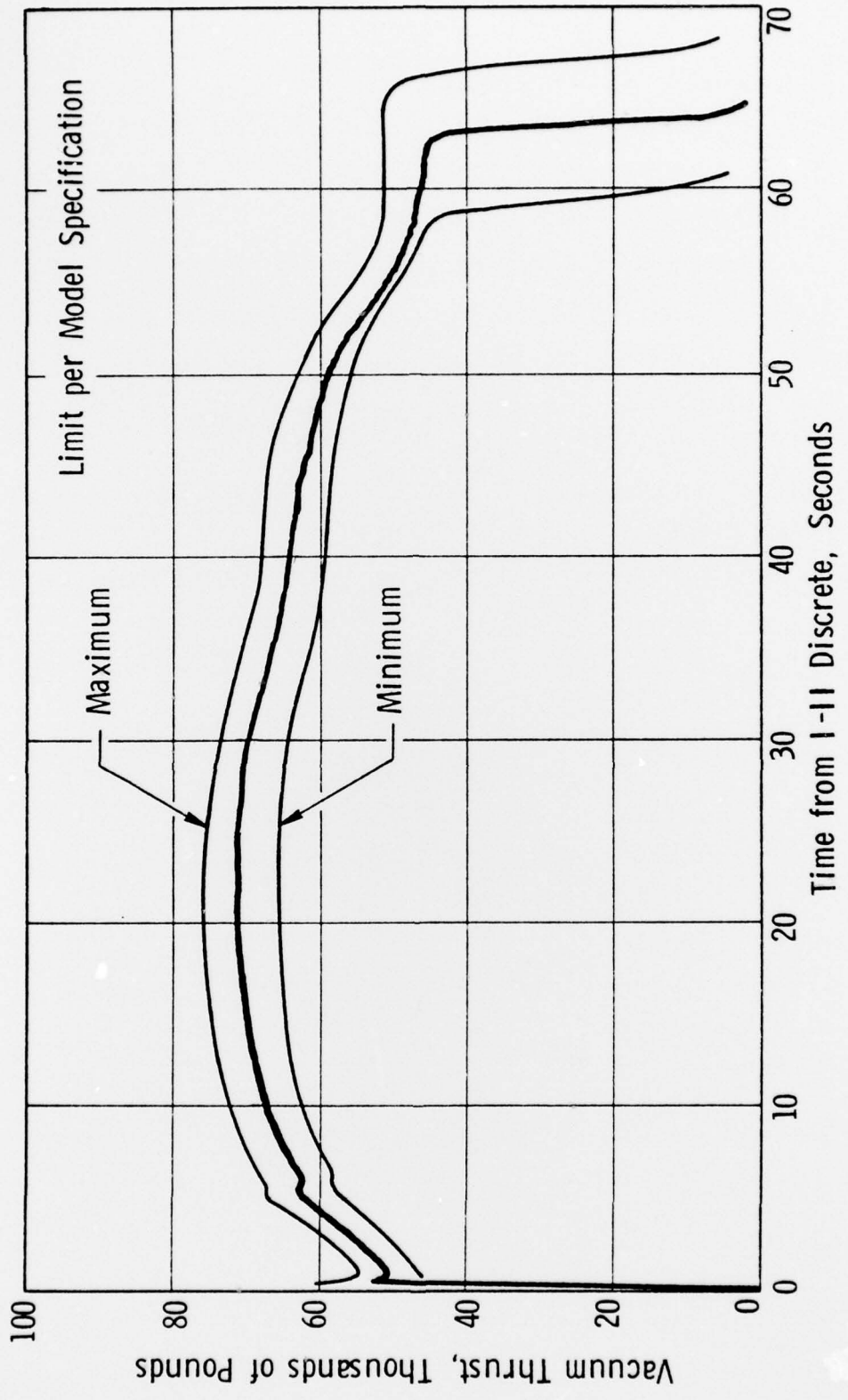
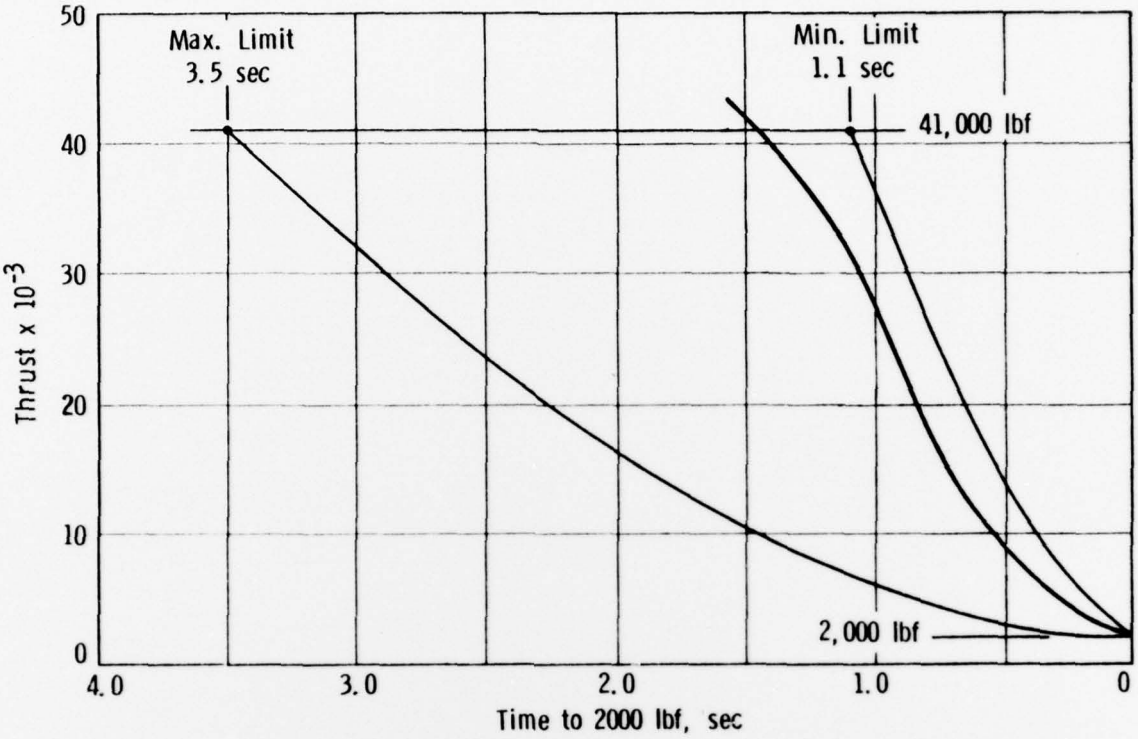
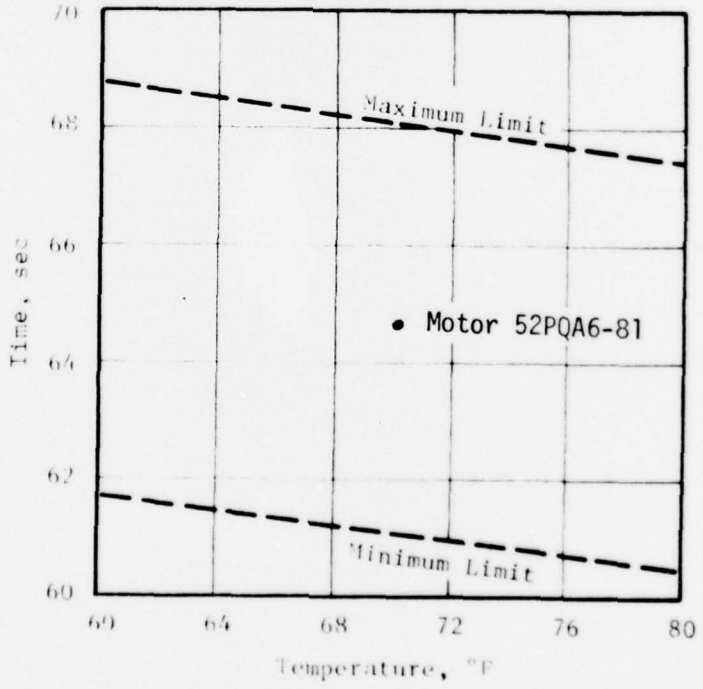


Figure 3

Vacuum Thrust vs Time, 60 to 70°F





Thrust and Temperature Data, End of Motor Action Time

Figure 4

Motor Data	Prefire
Total motor weight, lb	15,516.9
Total propellant weight, lb	13,744.2
Total inert weight, lb (including 265 lb Freon)	1,772.7
Center-of-gravity, in.	
X axis	116.126
Y axis	100.037
Z axis	99.970
System mass fraction	0.885
Nozzle throat area, sq in.	72.886
Nozzle exit cone area, sq in.	1807.9
Nozzle expansion ratio	24.8

Ballistic Data	As Fired (70°F)	80°F
Ignition delay, millisec	105*	
Max ignition pressure, psia	452	
Max interstage pressure, psia	Not available	
Action time, sec	64.45	63.8
Max chamber pressure, psia	540	545
Av chamber pressure, psia	465	470
Max vacuum thrust, lbf	70780	71490
Av vacuum thrust, lbf	61433	62050
Action time vacuum impulse, lbf-sec	3,959,373	
Propellant vacuum specific impulse, lbf-sec/lbm	288.18	
$\int P_{sn} dt$, psia-sec	29980	

*Estimated because of intervals of data dropout.

Derived Ballistic Data

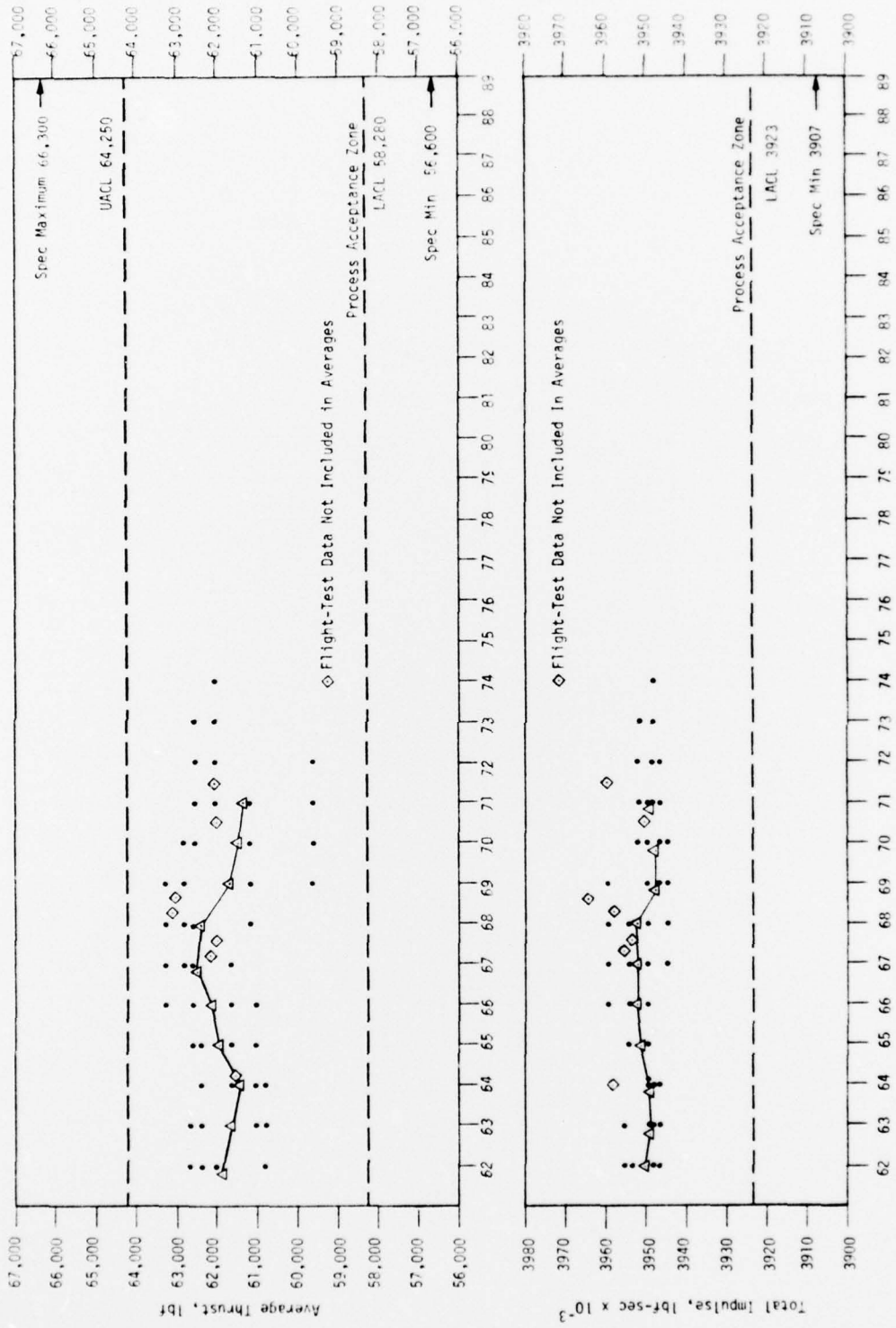
Figure 5

	Motor 52PQA6-81	Model Specification Limits
Motor action time at firing temperature	64.45	Figure 7*
Motor action time at 80°F, sec	53.8	Figure 7*
Thrust tailoff decay time, sec	1.49 (80°F)	1.48 to 3.54
Maximum chamber pressure at firing temperature, psia	540	1.48 to 3.54
Maximum chamber pressure at 80°F, psia	545	Figure 6*
Action-time impulse (60 to 80°F), lbf-sec**	3,353,373	3,907,000 (min)
Maximum thrust at firing temperature, lbf	70,780	Figure 1*
Maximum thrust at 80°F, lbf**	71,490	Figure 2*
Average thrust (60 to 70°F), lbf**	61,433	56,000 to 65,700
Average thrust at 80°F, lbf	62,050	56,000 to 66,300
Motor ignition delay (60 to 80°F), millisec	111 (est)	250 (max)
Predicted maximum interstage pressure, psia	Not Available	75 (max)
Gross motor weight, lb	15,516.9	15,626 (max)
Total Propellant Weight, lb	13,744.2	13,680 (min)
Weight of loaded Freon, lb	265	255 to 265
System mass fraction	0.885	0.884 (min)
Prefire center of gravity, in.***	55.311	53.2 to 56.8
Motor/nozzle throat alignment	0.002	0.046 (max)
Angular relationship, degrees	0.017	0.073 (max)

* Limits shown in curve form in specification.
** Vacuum conditions; excludes axial thrust augmentation.
***Measured aft of forward skirt

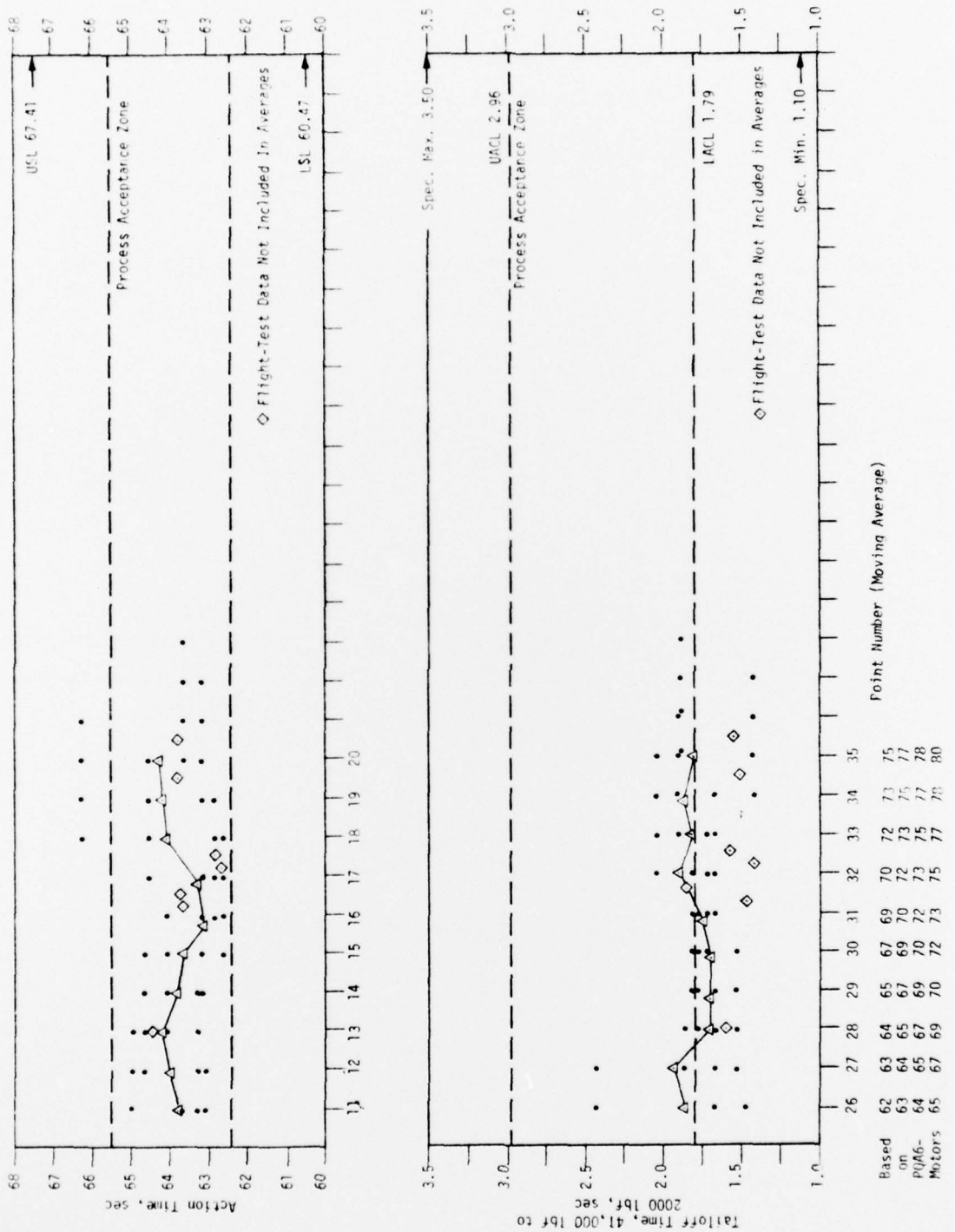
Comparison of Motor Performance with Model Specification Limits

Figure 6



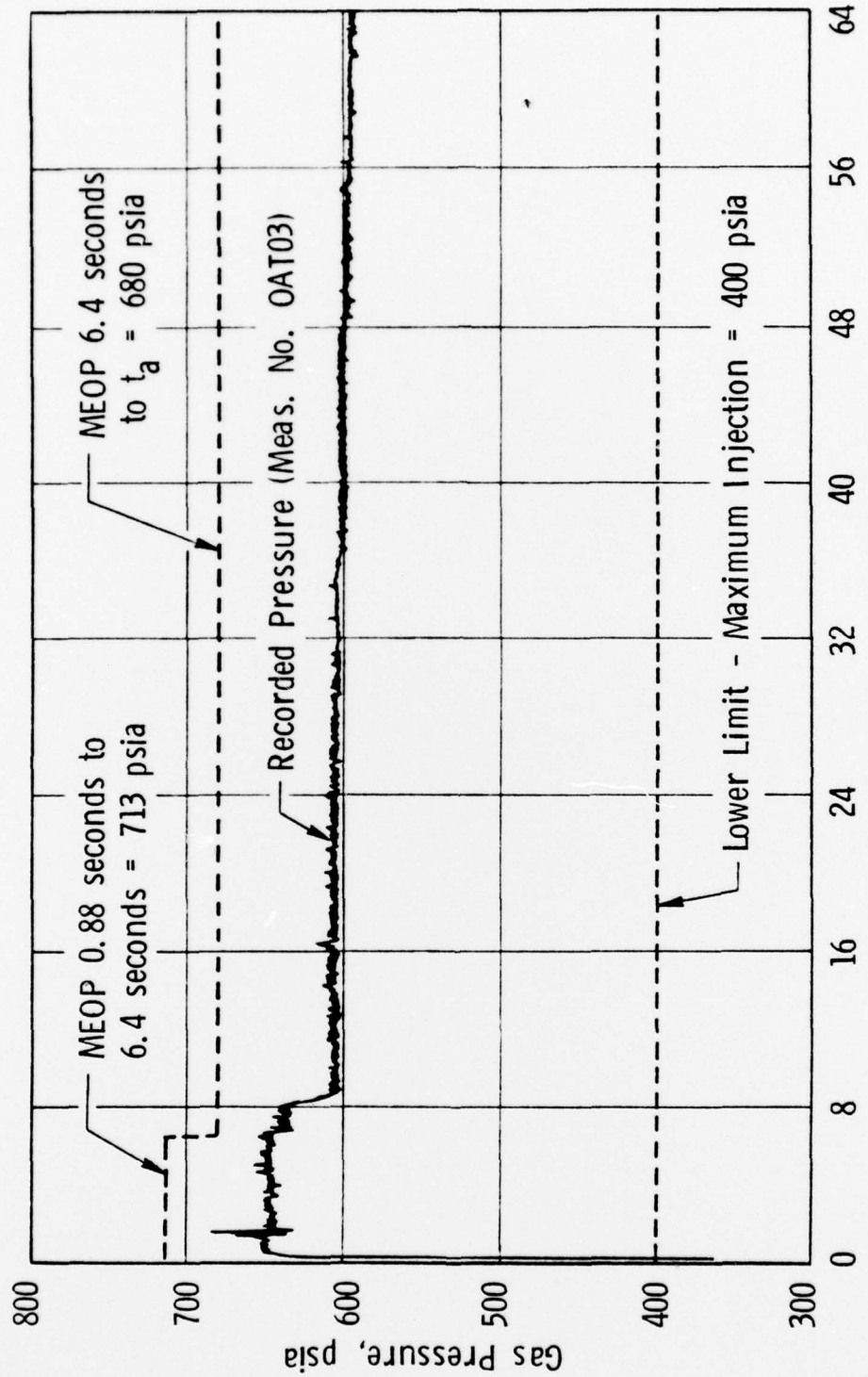
Acceptance Control Data, Average Thrust and Total Impulse

Figure 7



Acceptance Control Data, Motor Action Time and Thrust Decay Time During Motor Tailoff

Figure 8



Second Stage LITVC Manifold Pressure

Figure 9

Side Force Impulse	Measured or Calculated	Model Specification Requirements
Measured side force at 2.7 sec, lb	NA	3800 (min)
Measured jet deflection at 52.7 sec, degree*	NA	2 (min)
Pressurization Time, sec		
Time until first indication of pressure	0.143	0.880 (max)
Time until 500 psia in last injector cavity	0.453	0.950 (max)
Time until 1560 psia in roll control gas generator	0.162	0.700 (max)
Roll Control Response, sec		
Null to 90%	NA	0.035 (max)
Hardover to 10%	NA	0.050 (max)
Hardover to 90%	NA	0.050 (max)
Pressure, psia		
Maximum injectant pressure at 0 lb/sec flow rate	655	713 (max)
Minimum injectant pressure	591	560 (min)
Minimum injector pressure at full flow rate	NA	425 (min)
Maximum roll control gas generator pressure	2185	2400 (MEOP)
Roll Control gas generator pressure at end of motor action time	325	255 (min)
Torque, ft-lb		
Torque capability at 7.7 sec**	413	350 (min)
Torque capability at 15.7 sec**	144	120 (min)
Torque capability at end of Action time	89	70 (min)

* Measured from motor ignition

**Measured from gas generator ignition

LITVC and RC Performance Summary

Figure 10

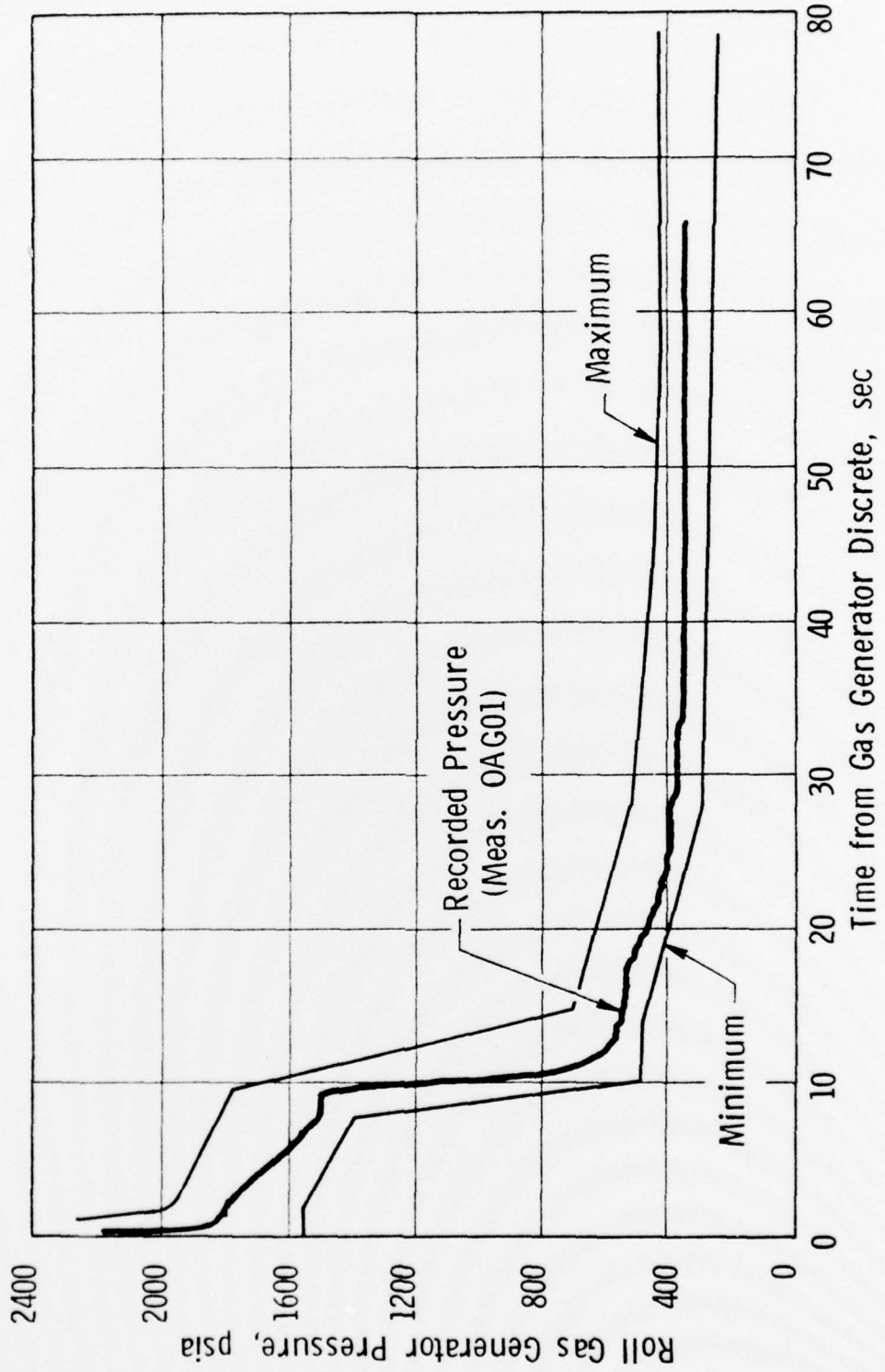
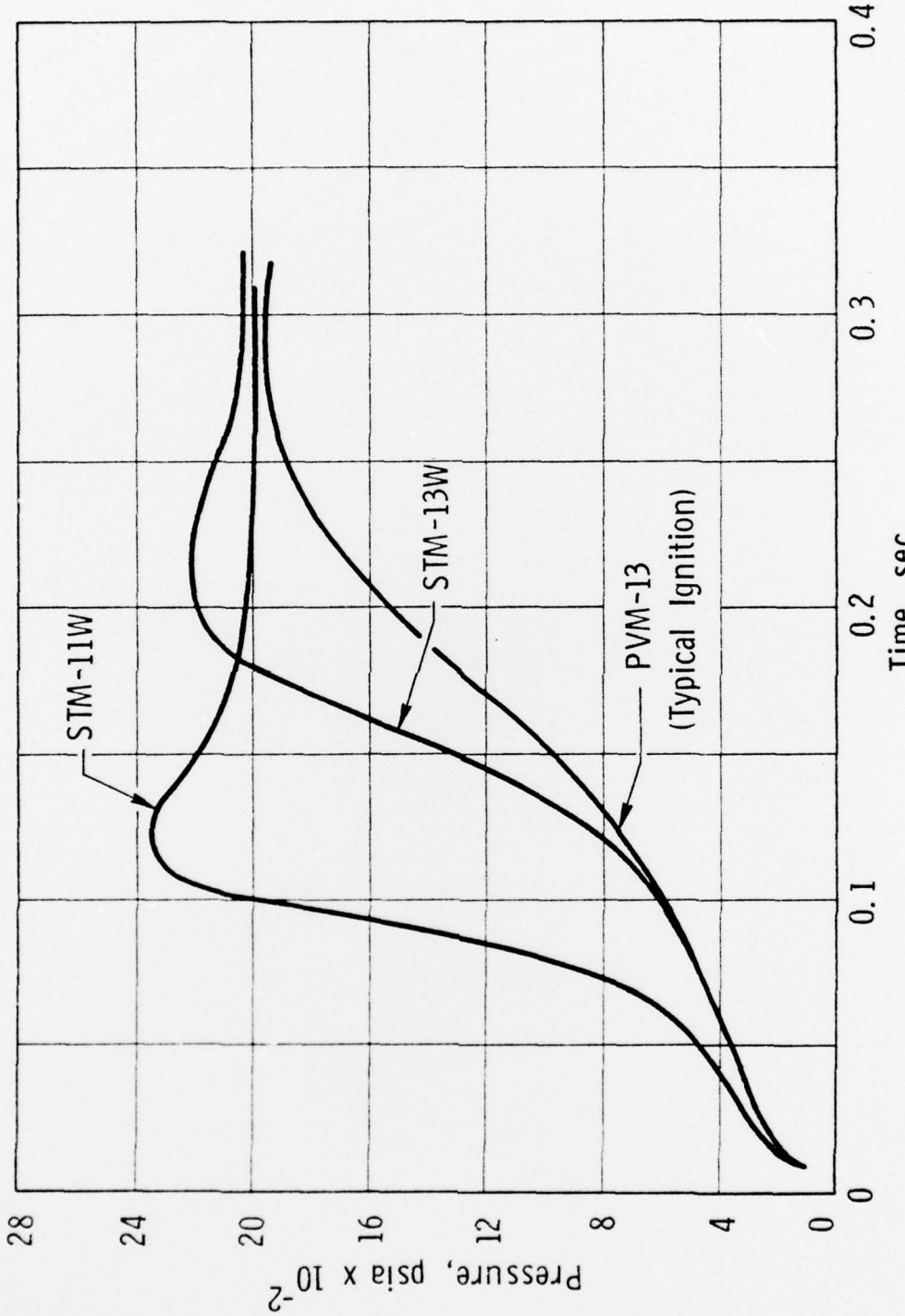


Figure 11

Second Stage Roll Gas Generator Pressure



Second Stage Roll Gas Generator Ignition Transient

Figure 12

AGCS 1920 7 (S) (REV 6 71)

WING VI POST-TEST RELIABILITY REPORT FORM

Test No.	(200)	Name of Contractor	Aerojet Solid Propulsion Company
Test Date	(202) (MO - DAY - YR) 01-30-77	Date form completed by Cont'r.	(MO - DAY - YR) 03-14-77
Motor SN	(205) STM-13W, FTM-5729 52 PQA6-81, AA21485	Signature of Contractor	L P Grimbergen
Motor Type	(207) WING VI Operational		P. E. Journey
Applicable Specs.	(208) S-133-1002-0-2		

Chamber Serial Number 7024009

MOTOR TEST DATA

If any of the following parameters are outside the applicable model specification limits, or exceeds predicted performance limits, indicate fact by asterisk in column before parameter.

	(240) Action Time Impulse, lbf. sec. (I_a)	3,959,373	
	(241) Average Thrust, lbf (F)	62,050	
	(242) Thrust curve within limits	YES [X] NO [ ]	(1)
	(243) Max. Thrust, lbf (F_{max})	71,490	
	(244) Specific Impulse, lbf sec/lbm (I_s)	288.18	(1)
	(245) Trajectory Action Time, sec (t_a)	63.80	
	(246) Average Chamber Pressure, Psia ($\bar{P}_{sn}$)	470	
	(247) Max. Chamber Pressure, (Psia)	545	
(1)	(248) Predicted Interstage Pressure, (Psia)		
	(249) Ignition Delay, sec (t_i)	0.105	
	(250) Ignition Peak Pressure Psia (P_i)	452	
	(251) Useful Propellant Weight, lbm (W_{pa})	13,739.2	
	(252) Motor Weight, (Gross) lbm (W_m)	15,516.9	(1)
	(253) System Mass Fraction (A_s)	0.886	
	(254) Grain Temperature, °F	70	
	(255) Thrust Tailoff Decay Time, sec	1.53	

TVC

(260) Max Side Thrust, lbf	
(261) Injectant Pressurization Time, sec	0.453
(262) Thrust-Vector Angle Within Limits	Yes [ ] No [ ]

ROLL CONTROL

(263) Max Gas Generator Pressure, psia	2185
(264) Pressurization Time, sec	0.162
(265) Roll Control Moment Within Limits	Yes [X] No [ ]

(266) Max Response Time, sec

O-HARDOVER	HARDOVER-O	HARDOVER-HARDOVER

Remarks about Performance

Motor flight test data converted to 80°F, based on estimated silo temperature of 70°F.

(1) Not available on flight tests.

TEST RESULT CLASSIFICATION

Legend: S, Success, F, Failure, PE, Pretest Exclusion, AE, Posttest Exclusion

CONFIGURATION	WING VI QUAL	WING VI OPER	WING VI OTHER	REMARKS
(270) SUBSYSTEM A		S		Subsystem classifications are based on satisfactory missile
(272) SUBSYSTEM B		S		performance during second-stage operation.
(273) SUBSYSTEM C		S		
(274) SUBSYSTEM D		S		
(274) SUBSYSTEM E		S		
(274) SUBSYSTEM F		S		

Post-Test Reliability Data

Figure 13